

STUDY ON THE POTENTIAL APPLICATIONS OF THE GEOCOMPOSITE  
CELLULAR MAT (GCM) FOR WATER QUALITY AND WALL RADIATION  
SHIELDING

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*I dedicated this thesis to my beloved parents and siblings for  
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## ABSTRACT

Derogatory human activities worldwide, coupled with population increase, has resulted in a variety of unsustainable geo-environmental challenges in areas such as water pollution, waste disposal and proliferation of electromagnetic radiations. Geocomposite Cellular Mat (GCM) is a green innovative product that is currently being researched, fabricated and developed within the **RECESS** research group at UTHM to provide an answer to some of the issues. The multiplicity of its design characteristics in being of cellular nature, lightweight and yet a stiff mat structure can meet customer demands on size and usage, promises a wide spectrum of potential applications of the product to meet some of these geo-environmental challenges. This research focuses on the potential usages of the product and these therefore, presents multidisciplinary testing carried out on the product. The possible applications of the GCM are as a filter medium for water flow transport and electromagnetic wave radiation shield. The cellular mat structure with appropriate sandwiching fabrics enable the GCM to be used as permeability controllable water filters, with added infill that will enable geo environmental cleansing of industrial effluents. The values achieved from the environmental test for several parameters such as total dissolved solid, total suspended solid and dissolved oxygen showed significant changes by using zeolites as infill. Furthermore, GCM cells filled in with aptly researched material (inorganic and / or organic) have been investigated in this research for their appropriateness in uses such as shields for electromagnetic radiation. Results from appropriate tests carried out for each of the applications and the appropriate environmental standards are presented in this thesis. Thus, it was found the GCM may be applied for enhancement of water quality and improve the radiation shielding of walls where required for building construction.

## ABSTRAK

Aktiviti manusia di seluruh dunia, ditambah lagi dengan peningkatan penduduk telah menyebabkan pelbagai cabaran terhadap alam sekitar yang tidak lestari seperti pencemaran air dan radiasi elektromagnetik. 'Geocomposite cellular mat' (GCM) ialah produk hijau yang inovatif yang sedang dalam kajian untuk direka dan dibangunkan oleh kumpulan penyelidikan **RECESS, UTHM** bagi mengatasi isu-isu alam sekitar tersebut. GCM yang dihasilkan menggunakan plastik kitar semula telah dapat menangani kemapanaan dalam penggunaan semula plastik. Dengan kepelbagaian ciri-ciri reka bentuknya seperti selular, ringan dan struktur mat yang kuat dapat memenuhi permintaan pelanggan terhadap saiz dan penggunaannya. GCM menjanjikan spectrum yang luas dengan kebolehan dan keupayaan aplikasinya untuk memenuhi sebahagian daripada cabaran geo-alam sekitar. Antara aplikasi GCM ialah boleh digunakan sebagai medium penapis aliran air dan perisai radiasi electromagnet. Struktur selular dengan fabrik yang sesuai membolehkan GCM digunakan sebagai penapis air, manakala dengan menambah infill yang sesuai akan membolehkan pembersihan geo-alam sekitar daripada pelepasan sisa industri. Selain itu, ujikaji yang dijalankan bagi mendapatkan parameter ujikaji alam sekitar memberikan hasil yang positif selepas menggunakan zeolites sebagai infill. Ujikaji juga telah dijalankan terhadap penggunaan infill (organik/bukan organik) bagi mengetahui kesesuaian penggunaan sebagai perisai radiasi elektromagnetik. Keputusan uji kaji bagi setiap aplikasi mengikut piawaian yang ditetapkan akan dibentangkan di dalam thesis ini. Kesimpulanya, GCM dapat diaplikasikan sebagai medium penapis air serta perisai elektromagnet bagi pembinaan bangunan.

## **CONTENTS**

<b>TITLE</b>	<b>i</b>
<b>DECLARATION</b>	<b>ii</b>
<b>DEDICATION</b>	<b>iii</b>
<b>ACKNOWLEDGEMENT</b>	<b>iv</b>
<b>ABSTRACT</b>	<b>v</b>
<b>CONTENTS</b>	<b>vii</b>
<b>LIST OF TABLES</b>	<b>xii</b>
<b>LIST OF FIGURES</b>	<b>xiii</b>
<b>LIST OF SYMBOLS AND ABBREVIATIONS</b>	<b>xviii</b>

## **CHAPTER 1 INTRODUCTION**

1.1	Preface	1
1.1.1	Mega scale use - for erosion pollution in water bodies	1
1.1.2	Macro scale uses - effects requiring filtration	2
1.1.3	Invisible scale uses- to reduce electromagnetic radiation effects	4
1.2	Problem statement	5

1.3	Research aim	6
1.4	Research objectives	6
1.5	Scope and limitations of study	6
1.6	Structure of thesis	8

## **CHAPTER 2 LITERATURE REVIEW**

2.1	Introduction to chapter	9
2.2	Current issues relating to water resources in Malaysia	
2.2.1	Malaysia rivers	9
2.2.2	Global water shortage	14
2.2.3	Water shortage in Malaysia	12
2.2.4	Water pollution	17
2.3	Water quality and control	
2.3.1	Water quality parameters	
2.3.1.1	Temperature	19
2.3.1.2	Turbidity	19
2.3.1.3	Suspended sediments	19
2.3.1.4	pH	20
2.3.1.5	Dissolved oxygen	20
2.3.1.6	Biochemical Oxygen Demand	20
2.4	Water Quality Index	21
2.5	Water filtration processes and technology	23
2.5.1	Water treatment plant and process	24
2.5.2	Current water filtration methods for	

	industrial applications	29
2.5.3	Current water filtration methods for domestic applications	34
2.6	Application of materials for wall construction	35
2.6.1	Structural insulated wall panels	36
2.6.2	Gypsum board	38
2.6.3	Noise reduction	39
2.7	Electromagnetic radiation	40
2.7.1	Electromagnetic shielding	42
2.8	Summary to chapter	44

### **CHAPTER 3 METHODOLOGY**

3.1	Introduction to chapter	46
3.2	Research flow and schedule	46
3.3	GCM as water quality filtration material	47
3.3.1	Water samples	48
3.3.2	Geocomposite cellular mats	51
3.3.3	Geosynthetics fibres	54
3.3.4	Fillings	58
3.3.5	Natural zeolites	58
3.3.6	Fabrication of permeameter cell	60
3.3.7	Constant head permeability test	62
3.3.8	Introduction	62
3.3.9	Test procedures	63



3.4	GCM as wall radiation shielding material	64
3.4.1	Permittivity test	64

## **CHAPTER 4 RESULTS AND ANALYSIS**

4.1	Introduction to chapter	69
4.2	GCM as filtration material	69
4.2.1	Permeability test	70
4.3	GCM as water quality control	72
4.3.1	Environmental test	73
4.3.2	Observation from Total Dissolved Solid (TDS) graph analysis	74
4.3.3	Observation from Total Suspended Solid (TSS) analysis	75
4.3.4	Observation from Biochemical Oxygen Demand (BOD) analysis	75
4.3.5	Observation from Chemical Oxygen Demand (COD) graph analysis	77
4.3.6	Observation from Dissolved Oxygen graph analysis	80
4.3.7	Observation from Turbidity graph analysis	81
4.3.8	Observation from pH graph analysis	82
4.4	GCM as wall radiation shielding material	84
4.4.1	Choices of equipment and fillings	85

4.4.2	Observation of the TEM coaxial cell	
	graph analysis	87
4.4.3	TEM parallel plate calibration using Teflon	88
4.4.4	Observation and analysis from empty GCM	89
4.4.5	Observation and analysis of carbon filled GCM	91
4.5	Summary to chapter	93
<b>CHAPTER 5 CONCLUSION</b>		
5.1	Introduction to chapter	94
5.2	Conclusion for the literature review (Objective 1)	95
5.3	Conclusion for the use of GCM as water quality	
	filtration material (Objective 2)	96
5.3.1	Permeability test on GCM with and	
	without infill	97
5.3.2	Environmental tests on GCM	97
5.4	Conclusion for the use of GCM as wall radiation	
	shielding material (Objective 3)	97
5.5	Potential uses of geocomposite cellular mat	98
5.6	Recommendations for further research	99
<b>REFERENCES</b>		100
<b>VITA</b>		110

## LIST OF TABLES

1.1	Thesis outline	8
2.1	Quality of river waters from 1987-2002	12
2.2	Domestic and Industrial Water Demand (million m <sup>3</sup> )	16
2.3	Malaysia water quality index class	21
2.4	Excerpt of International Water Quality Standard	22
2.5	INWQS class definition	22
2.6	Advantages and limitations of reverse osmosis process	33
3.1	Coefficient of permeability in different soil.	63
4.1	The water quality parameters for Parit Nipah, Johor and Sungai Semenyih, Selangor before treatment.	73
4.2	The water quality parameters for Parit Nipah, Johor and Sungai Semenyih, Selangor after treatment	73
4.3	Data comparison between author's and M.Halim Shah et al. and Milan M. Lakdawala et al.	79
5.1	Conclusion for the objectives of the study	95
5.2	Opinion of the potential uses of GCM	98

## LIST OF FIGURES

1.1	Research flow chart	8
2.1	Peninsula Malaysia river network map	11
2.2	Malaysia river	12
2.3	Water stress indicators in major river basins	13
2.4	Dried up well in Guizhou Province	13
2.5	Malaysia annual water balance.	15
2.6	The depleting level of water at Sungai Selangor dam.	15
2.7	Residents stocking up water from Syarikat Bekalan Air Selangor (SYABAS) truck.	16
2.8	The total consumption of water for domestic and non-domestic uses in Malaysia for 2010 and 2011.	17
2.9	Polluted river in Sungai Tebrau, Johor	18
2.10	The typical water treatment process	24
2.11	Hulu Semenyih dam.	25
2.12	Jenderam Hilir intake station.	26
2.13	Water treatment plant in Precinct 19, Putrajaya.	26
2.14	Sedimentation tank.	27
2.15	Treated water pumping station.	28
2.16	Membrane filtration spectrums.	30
2.17	Schematic representations of the principle membrane modules.	31
2.18	Membrane filters used by Malaysia Diamond Water Company for water filtration.	31
2.19	Products of Lifestraw® and Lifestraw® Family 1.0 by Vestergaard.	36

2.20	Several water filters that are available in the market.	37
2.21	SIP's structure which consist of foam core and surrounded by structural sheathing	38
2.22	Uses of steel frame to improve wind resistivity and structure stabilizing.	39
2.23	The typical gypsum board wall assembly.	40
2.24	Source and victim of EMI, coupling path.	43
2.25	Electromagnetic wave transmissions through walls.	43
2.26	The transmission configuration when the EM passes through the sample.	45
3.1	Flow of the research.	47
3.2	Generalized map of Peninsula Malaysia showing the locations of the sites.	48
3.3	Sungai Semenyih Water Treatment Plant, Precint 19 Putrajaya location at 2°90'18.5''N and 101°68'84.1''E.	49
3.4	Parit Nipah, Johor location at 1°88'38.8''N and 103°11'94''E.	49
3.5	The well at Parit Nipah, Johor for water samples collection	50
3.6	The surrounding area at Parit Nipah, Johor.	50
3.7	The water treatment plant in Sungai Semenyih, Putrajaya.	51
3.8	GCM of 50mm in height used for water filtration test.	52
3.9	GCM of 25mm in height used for wall radiation shielding.	52
3.10	Hexagonal-shaped GCM prototype.	53
3.11	Possible variation of GCM for other usages.	53
3.12	Variation of non-woven geotextile fibres.	54
3.13	Non-woven geotextiles from Shanp Deng Enterprise (Asia) Sdn Bhd.	55
3.14	Formation of an upstream soil filter.	56
3.15	Upstream particles blocking geotextiles opening.	56
3.16	Upstream particles arching over geotextile.	57
3.17	Soil particles clogged within geotextile structure.	57

3.18	Carbon powder used for experiment.	58
3.19	Natural zeolites used as filling.	59
3.20	Conventional permeameter cell	60
3.21	The first prototype of the permeameter cell	61
3.22	The second permeameter cell made from stainless steel	61
3.23	The complete set up of the permeameter cell	62
3.24	The complete set up of the parallel plate connected to the vector network analyser.	65
3.25	A sample inside the TEM parallel plate before testing.	65
3.26	The geocomposite cellular mat sample that is used for the permittivity test before carbon and fabric is applied.	66
3.27	Teflon sample for calibration purpose.	66
3.28	The complete set up of the coaxial cell connected to the vector network analyzer.	67
3.29	The 5.5 cm diameter geocomposite cellular mat sample that are used for the permittivity test.	67
3.25	GCM sample with zinc filling.	68
4.1	Variation of head loss against time for empty GCM	70
4.2	Variation of head loss against time for zeolites filled GCM	71
4.3	Variation of velocity against hydraulic gradient of empty GCM	72
4.4	Variation of velocity against hydraulic gradient when zeolites are present.	72
4.5	The Total Dissolved Solid (TDS) graphs for Sungai Semenyih and Parit Nipah	75
4.6	The Total Suspended Solid (TSS) observed for Sungai Semenyih and Parit Nipah.	77
4.7	The Biochemical Oxygen Demand (BOD) observed for Sungai Semenyih and Parit Nipah.	79
4.9	The Chemical Oxygen Demand (COD) graphs for Sungai Semenyih and Parit Nipah.	81

4.9	The Dissolved Oxygen (DO) graphs for Sungai Semenyih and Parit Nipah	82
4.10	The Turbidity level for Sungai Semenyih and Parit Nipah.	83
4.11	The pH graphs for Sungai Semenyih and Parit Nipah	84
4.12	Variations of the transverse electric and magnetic (TEM) equipment used during experimentation	86
4.13	GCM sample with zinc filling	86
4.14	Graph results of the zinc filling using the TEM coaxial cell.	87
4.15	Graph results for calibration using Teflon	88
4.16	The Teflon sample	89
4.17	The complete set up of TEM parallel plate before calibration process	89
4.18	The graph results of empty GCM using TEM parallel plate	90
4.19	Comparison of Teflon and empty GCM	90
4.20	The graph results of carbon filled GCM using TEM parallel plate	91
4.21	Comparison of graphs between (Yee, Mohd Jenu, 2013) and the author's.	92
4.22	Comparison of data for SE of GCM with and without carbon	92

## LIST OF SYMBOLS AND ABBREVIATIONS

<i>BOD</i>	Biochemical Oxygen Demand
<i>DID</i>	Department of Irrigation and Drainage
<i>DO</i>	Dissolved Oxygen
<i>DOE</i>	Department of Environment Malaysia
<i>EM</i>	Electromagnetic
<i>EMI</i>	Electromagnetic Interference
<i>EMR</i>	Electromagnetic radiation
<i>EPA</i>	United States Environmental Protection Agency
<i>GCM</i>	Geocomposite Cellular Mat
<i>GLASOD</i>	Global Assessment of Human-Induced Soil Degradation
<i>HT</i>	High tension
<i>MF</i>	Microfiltration
<i>NAHRIM</i>	National Hydraulic Research Institute of Malaysia
<i>NGO</i>	Non-Governmental Organization
<i>NST</i>	New Straits Times
<i>SE</i>	Shielding Effectiveness
<i>SIP</i>	Structural Insulated Panel
<i>SS</i>	Suspended solid
<i>SYABAS</i>	Syarikat Bekalan Air Selangor
<i>TDS</i>	Total Dissolved Solid
<i>TSS</i>	Total Suspended Solid
<i>TEM</i>	Transverse Electric and Magnetic
<i>UF</i>	Ultrafiltration
<i>UN</i>	United Nations
<i>UNESCO</i>	United Nations Educational, Scientific and Cultural Organization



<i>UNFCC</i>	United Nations Framework Convention on Climate Change
<i>UNWWAP</i>	United Nations World Water Assessment Programme
<i>USEPA</i>	United States Environmental Protection Agency
<i>WHO</i>	World Health Organization
<i>WQI</i>	Water Quality Index

## **CHAPTER 1**

### **INTRODUCTION**

#### **1.1 Preface**

Research and technology stands out today as a mega trend for its ubiquitous impact on major global aspects such as the social, health, economic and political lives. The economic landscape is changing from the agriculture, manufacture and service based drivers to knowledge and innovative-based economies. New platform of knowledge for innovative product development are founded on multi- / inter- / and trans-discipline approach. This research study assesses the academic/ research/ industry benefits and potential applications of geocomposite cellular mat to be produced from acquired plastic waste. The author presents its potential applications listed and briefly outlines them below.

##### **1.1.1 Mega scale use - for erosion/pollution in water bodies**

Rapid urbanization and the increase in human population have caused great demand on lands to be utilised mainly for agricultural purposes and other human activities. Accordingly, this has led many countries to raise major concerns on land degradation and the increase in demand for clean potable water. Degradation is defined as the adverse changes which reduced capacity of the land to function as desired (initially planned). One of the contributing factors of degradation is a consequence of soil erosion. Soil erosion follows the weathering process caused by water, air or ice and

such processes cause major catastrophes such as landslide and siltation of the river systems. According to the findings by Global Assessment of Human-Induced Soil Degradation (GLASOD), it is estimated that 55% of degraded soil suffer from soil erosion by water.

Erosion process causes the removal of top soil until only the sub soil is left. As the sub soil is less permeable, it will further contribute to the erosion process. Although erosion is a natural process, it causes problems to the ecosystem particularly if it happens faster than the formation of soil. Human activities such as deforestation, agriculture and construction have further instigated the eroding rate of the soil. Human activities increased the erosion rates tenfold compared to all natural processes combined together (Wilkinson, 2004). The United States is currently losing 10 times faster; China and India are losing 30-40 times faster than natural replenishment rate. Soil erosion also impacts on the economy as it is estimated that cost of damage from soil erosion worldwide amount to 400 million USD per year (Pimentel, 2006). According to National Hydraulic Research Institute of Malaysia (NAHRIM), the human-induced rate of erosion at Klang Valley itself amount up to 2950 tonnes/sq. km/yr. One of the effects of erosion is transportation of sediments into the fluvial system and about 60 per cent of soil that is washed away ends up in rivers and streams which then causes the waterways to be more prone to flooding and be contaminated with waterborne pollution such as pesticides. This is an application where geocomposite cellular mat (GCM) can be utilised as a part of sediment trap.

### **1.1.2 Macro scale uses- effects requiring filtration**

One of the impacts of the erosion process is sedimentation. Sedimentation process contributes to the build-up of environment such as the formation of deltas and estuaries. Nevertheless, excessive sedimentation process could cause serious geo environmental problems in the long run. The impacts of sedimentation are clogging of pipes, drains, the damages to hydroelectric turbines, impairment of the ecosystem and river pollution as a result of excessive amount of suspended soil that settles and accumulates at the river bottom. Moreover, heavy rainfall also resulting in the transportation of heavy silt loaded into lower stretches of Malaysian rivers. The main reason for excessive sedimentation is due to consequences of widespread land clearing. Studies in Malaysia have shown that 90% of total sediment loads in rivers came from

the construction sites and 1 million m<sup>3</sup> of silt needed to be removed from Klang River annually (Chan, 2008). Sediment pollutions will result in disruption of river ecosystem, as the sediments will smother the gravel bed that is used by fish to lay eggs and it decreases oxygen level in rivers as sunlight is blocked due to turbidity. In addition, more money is needed to filter or dredge out the sediments in order to increase the water quality for domestic purposes.

Various methods can be used to mitigate and prevent sediment settlement into rivers and one of them is by using certain geotextiles. Geotextiles also called filter fabrics have been designed according to the functions needed. One of the applications of geotextiles is filtration. For filtration, geotextiles allow liquid to pass through while retaining and protecting the soil. Example of the application of geotextiles is that it can be used during construction by applying silt fence around the site to prevent sediments from being transferred into nearby drainage and river system.

Impacts of Malaysia economic and population growth has caused water imbalance in some of the regions especially in the developed and highly populated areas such as Kuala Lumpur. Moreover, 2014 water crisis that affected Klang Valley is an example of such occurrence in Malaysia. The increase in demands is particularly due for the purpose of consumption as well as productions.

In addition, industrial activities are a significant cause for poor water quality. As in accordance with the United Nations World Water Assessment Programme (UNWWAP), the industry and energy production use accounts for nearly 20% of total global water withdrawals and this water are returned to its source in degraded condition (UNWWAP, 2009). Wastewater from the industrial facilities such as the power plants and manufacturing plants contribute to poor water quality around the world. This wastewater contains waterborne pollutants such as microbiological contaminants, heavy metals and chemicals. As water is an essential natural resource, it is necessary to manage our resources carefully as human activities can have a devastating effect on the environment. In order to do this, the water quality must be improved by using a sustainable approach that is not detrimental to the environment.

Moreover, the population growth has also increased the amount of household waste that goes into the landfill. In general, Malaysians generates around 25,000 metric tonnes of waste every day. The current main approach to manage the household waste is landfill but the shortages of landfill due to lacks of new land are forcing the authority to find other sustainable approach in managing the wastes. From Malaysia's Second

National Communication Report to United Nations Framework Convention on Climate Change (UNFCCC), Malaysia plan to achieve the 22% recycling rate by 2020. In order to achieve this goal, we have come up with a solution by reusing the plastic waste that is available in the landfill thus reducing its number. From this study, geocomposite cellular mat is investigated as a proposal to mitigate some of the geo environmental challenges that our country is currently facing.

### **1.1.3 Invisible scale- to reduce electromagnetic radiation effects**

As Malaysia is trying to accomplish one of its visions that is becoming an industrialised nation by year 2020, it also causes several geoenvironmental problems such as shortage of land and proliferation of stray magnetic fields. These are consequences of the profound impacts of population growth and human activity.

Currently, there is an increase in High Voltage Power distribution works especially in the city and the rural areas. It has somewhat become a necessity in order to provide power to remote areas as well as to accommodate the demands required from the consumers. Electricity is generated at power stations and distributed via transmission lines/grid. High Voltage (between 132Kv to 755kV) electricity are transmitted from power station to substation. Then, at the substation the voltage is lowered to 132kV before being transmitted to the regional electricity companies which then distribute the electricity to the consumers at even lower voltage.

Moreover, as more residential areas have expanded in order to meet the housing demands, more homes are being built near or immediately under the high voltage electricity lines. Medical research indicates that there is an apparently associated increase of cancer related diseases that are rampant in those who have their abodes near these high-tension (HT) power cables. The electromagnetic flux created by these and even to a lesser extent those created by mobile phones are being defined as the cause for such problems and this GCM provides a possible means of forming the needed Electromagnetic barrier.

## **1.2 Problem statement**

Due to intense pressure in becoming an industrialised nation by 2020, leads Malaysia to face serious geo-environmental problems such as water scarcity, shortage of lands,

proliferation of stray electromagnetic fields and management of solid waste. Moreover, these particular problems have also affected many other developing countries around the world due to the profound impacts of human activity and population growth. The impacts of population growth and human activity itself have particularly increased the demand on water for the purpose of consumption as well as productions. Water a vital resource which used to be abundant has now become a scarcity.

Technological development and the associated HT Power supply network also causes undesirable Electromagnetic radiation effects on human health.

Most of these geo environmental problems are interrelated to one another. For example, uncontrolled constructions have caused the forest to be cleared thus, increasing the chances of erosion process that can pollute the rivers with sediments that was transported. Soil erosion can happen naturally because of natural transportation process such as by wind, air and glacial but human activity has instigated the rate of erosion to increase significantly over the years. The sediment that was transported into the rivers has decrease the water quality, thus increasing the cost on water treatment and filtration process.

Furthermore, shortage of suitable lands and landfill are some of the problems related to rapid urbanization. The amount of wastes produced has put a pressure on the government to find a more sustainable approach in dealing with this situation. For example, in 2006 Malaysia generates about 7.34 millions of waste, enough to fill 42 buildings (Siraj, 2006). One of the materials that made up the solid waste composition is plastic, which can be found abundant in landfill. To overcome these, the government has introduced 3R'S program which is Reuse, Recycle and Reduce. Although, the recycling activity in Malaysia is growing, the industry itself needs to be improved (Saeed et.al, 2013).

In order to overcome these challenges in this research work, an innovative and sustainable construction product was designed for water filtration purpose and as a radiation shielding. This particular product that is being researched is a lightweight geocomposite cellular mat which is a multipurpose product that can be used in road construction, lightweight low cost building panel and air filters. Any new and innovative product development must necessarily be followed by market search for its uses. The search for the multiplicity of uses and making certain they meet requirements provides a platform for commercialisation of the product.

### **1.3 Research Aim**

The aim of this research is to identify and assess the multiplicity of potential applications of the geocomposite cellular mat (GCM) as water filters and radiation shield wall.

### **1.4 Research Objectives**

To achieve the above aim, the specific objectives of this thesis are:

- i. To carry out comprehensive literature review and further study of construction practices to meet the geoenvironmental challenges, the existing water treatments, different type of fillings and electromagnetic radiation shielding.
- ii. To conduct hydraulic conductivity test and environmental test on the empty geocomposite cellular mat as well as with fillings.
- iii. To measure the permittivity value of geocomposite cellular mat when empty and with filling using Transverse Electric and Magnetic (TEM) parallel plate.

### **1.5 Scope and Limitations of Study**

This study focuses primarily on the multiplicity of applications of geocomposite cellular mat (GCM) as a filter and electromagnetic radiation shield. Moreover, the duration taken for this research was 2 years and the tests were mostly conducted at UTHM as well as at Konsortium Abass Sdn Bhd. Literature review provided the necessary fundamental information and background, while research plan was developed for lab experimentation to examine the components required for this study. Furthermore, personal communication with expert in this field through phone and email provided current significant information and guidance. The types of test conducted during the research were constant head test, environmental test and permittivity test. For this research, it does not cover all the necessary parameters for drinking water quality and only covers turbidity, pH, total suspended solid (TSS), total dissolved solid (TDS), dissolved oxygen (DO), biochemical oxygen demand (BOD) and chemical oxygen demand (COD).

## 1.6 Structure of thesis

The organization of this thesis is as follows. This thesis is divided into 5 chapters specifically introduction, literature review, research methodology, results and analysis of laboratory experiment as well as the summarisation of research work and detailed recommendations for future work.

Chapter one will briefly describes the background of this research, aim, objectives, problem statement, scope and limitations of study with special references to geoenvironmental challenges that Malaysia is currently facing and finally the research flow for this study.

Chapter two which is the literature review will focus on the water shortage, water pollution, water quality and control, current water filtration techniques for domestic and industrial usage, non-load bearing wall and proliferation of electromagnetic waves. The literature review presented from various sources and researchers are acknowledged accordingly.

Subsequently, chapter three presents the research methodology. This chapter presents the research framework to produce this study and discusses the required data and information needed. Additionally, this chapter presents the experimental method adopted in this research. Tests such as constant head permeability test, environmental tests and the permittivity test. Additionally, details of sample collections, standard laboratory testing procedures and development of equipment are discussed in this chapter.

Chapter four presents the data collected from lab testing and the analysis of the results. This chapter evaluates the analysis of the experimental results obtained from various experimental testing and comparing some of the parameters with the results gain from industrial testing.

Finally, chapter five outlines the summary of the research study and detailed recommendations for future research based on the current research work. Furthermore, the importance of this research for knowledge is discussed in this chapter so that new findings can be established.



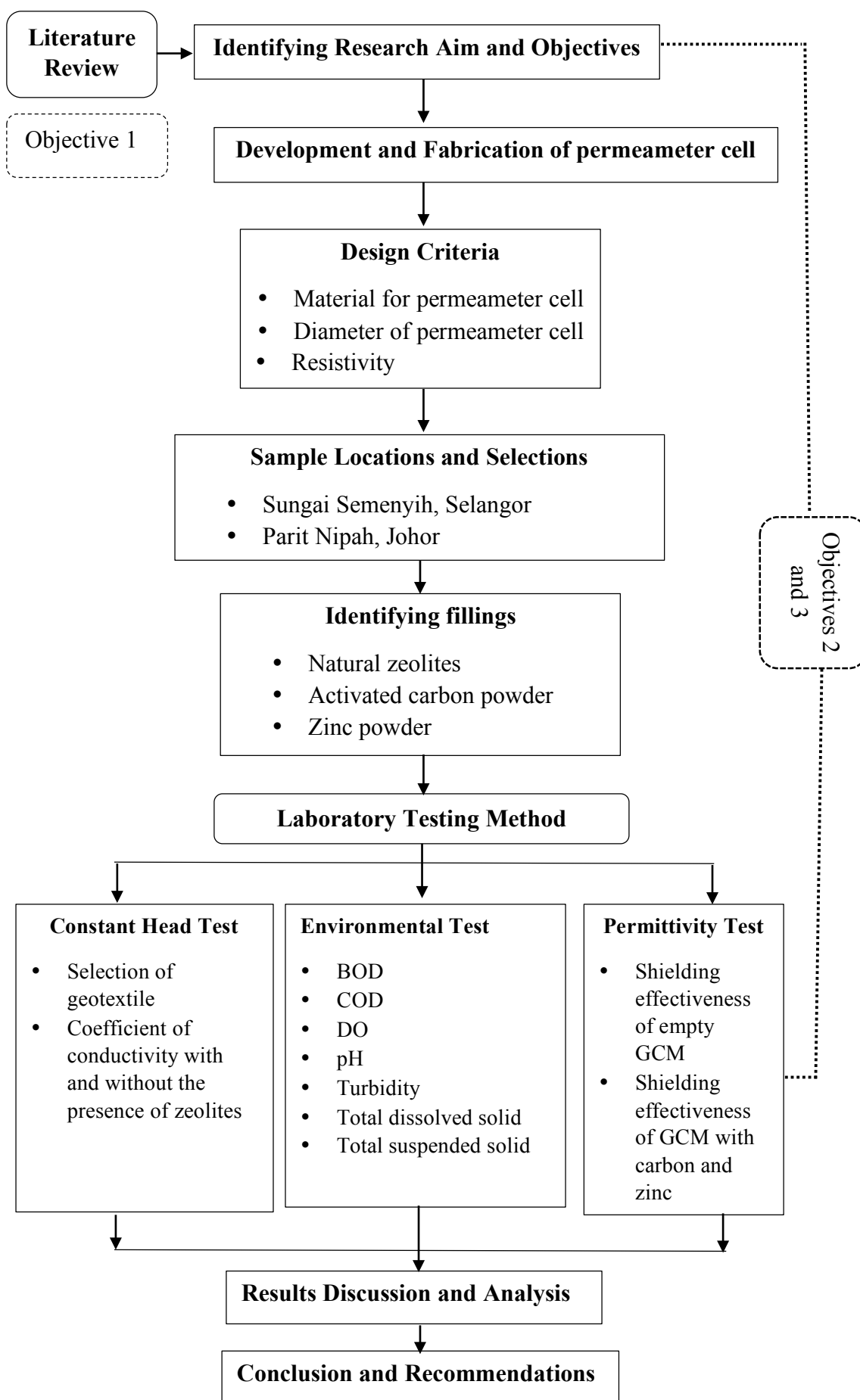


Figure 1.1 Research flow chart

## **CHAPTER 2**

### **LITERATURE REVIEW**

#### **2.1 Introduction to chapter**

Nowadays, there are many materials being used in construction to enhance the quality and design life. In this chapter, the literature will focus on the application of geocomposite cellular mat especially in civil and construction engineering. This chapter discusses some significant elements such as water scarcity, water quality and control, water filtration processes and technology as well as electromagnetic proliferation. Further illustration on the application of geocomposite cellular mat are shown in **Sections 2.4, 2.5 and 2.6**.

#### **2.2 Current issues relating to water resources in Malaysia**

##### **2.2.1 Malaysia river**

Management of rivers in Malaysia is currently a central issue for the central government and the non-governmental organizations (NGOs) as many rivers are currently in an unacceptable state. Agricultural and industrial waste products are currently being discharged into rivers by irresponsible people without any treatment particularly in urban areas. The end products usually consist of suspended solids and harmful chemicals such as arsenic, lead and cadmium. The study by (Keizrul, 2002), showed that the rivers that pass through the urban areas suffer the worst degradation

and are subjected to heavy liquid and solid disposal from squatter settlements and excessive silt loads from land clearing.

Moreover, an emergent number of contaminants are being detected in water that come from agricultural and industrial uses. Also, this number continue rising as more chemicals are manufactured and industries continue to grow every year. Stephenson (2009), estimated that around 700 new chemicals are introduced in the United States each year and globally, pesticides usage is approximately 2 million metric tonnes. These human-produced organic and synthetic chemicals that include pesticides and toxins can persist in the environment and be transported to other regions where it was not produced (Carr and Neary, 2008). Besides, these subsurface contaminants endanger the human lives, environment and increase operation costs for water treatment.

The water quality is measured by the pollutants in the rivers in terms of Biological Oxygen Demand (BOD), Suspended Solids (SS) caused by erosion and sedimentation process and emission of Ammonia Cal Nitrogen ( $\text{NH}_3\text{-N}$ ). This also showed that the polluted rivers are mainly affected by pollutants such as suspended solids and Ammonia Cal Nitrogen. Moreover, the overall rate of change also indicates negative trend for all pollutants.

In 2001, DOE began again the monitoring of 931 sampling stations in 120 river basins instead of river-based reporting. Data observed showed that the numbers of polluted sampling stations are 135 (13%), 303 (33%) are slightly polluted and 489 (53%) are found to be clean. (See **Table 2.1**)

The **Figure 2.1** below shows the river network map for Peninsula Malaysia. Currently, there are 146 river basins in Malaysia which 120 river basins located in Peninsula Malaysia and another 26 river basins located in Sabah and Sarawak. A total of 146 river basin was monitored in year 2006. 80 river basins were considered clean, 59 were slightly polluted and 7 polluted. All of the polluted river basins were located at Peninsula Malaysia with Johor topping the list. Generally, the polluted river were located in the industrial area which are Sungai Pinang and Sungai Juru in Penang, Sungai Buloh in Selangor as well as Sungai Danga, Tebrau, Segget and Pasir Gudang situated in Johor. This results showed improvement from the year 2005, which 80 river basins were clean, 51 slightly polluted and 15 polluted. Figure 2.2 shows the example of river located in our country.

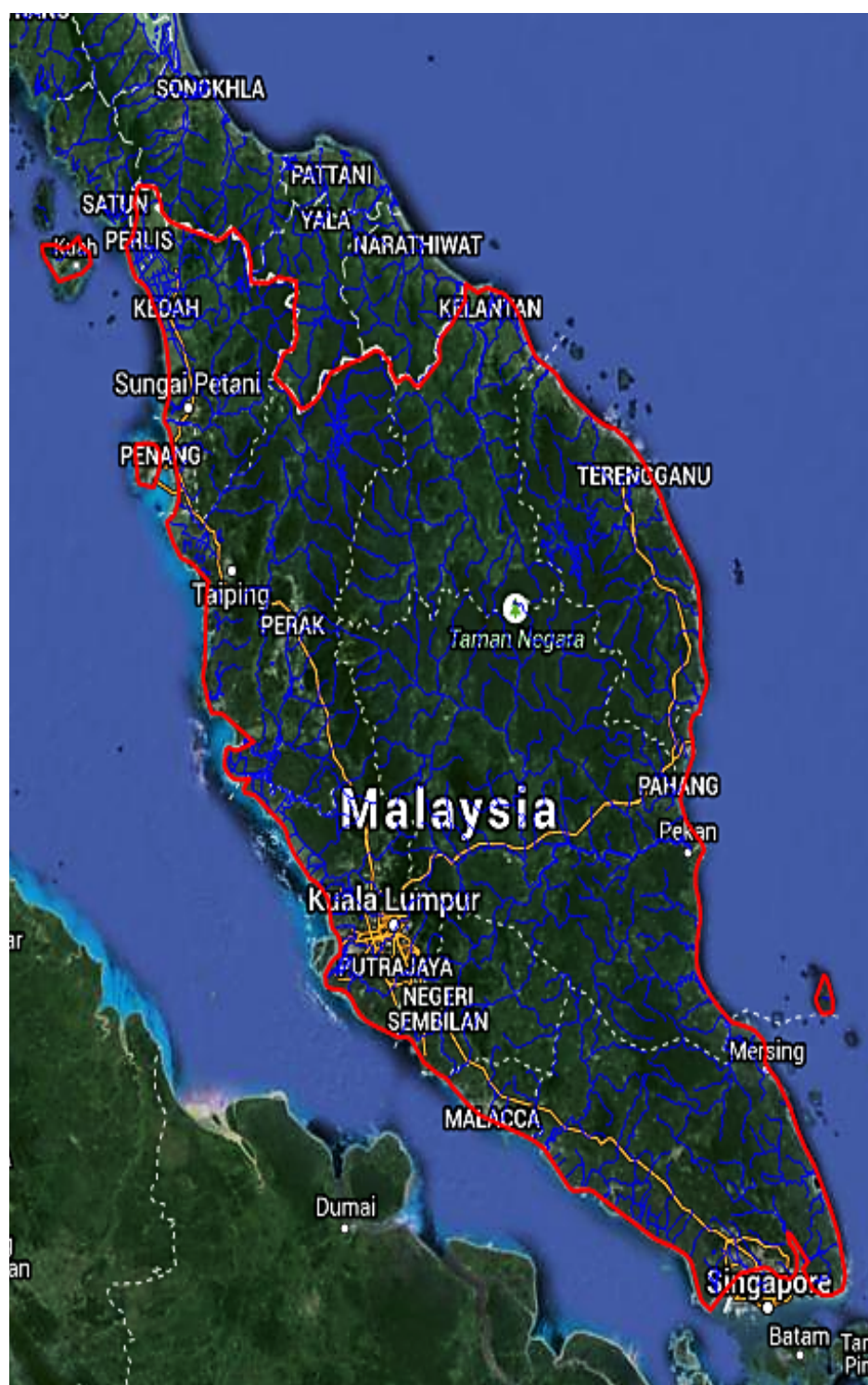


Figure 2.1: Peninsula Malaysia river network map  
(Source: [www.rivernetworks.org](http://www.rivernetworks.org))



Figure 2.2: Malaysia River

(Source: [www.google.com](http://www.google.com))

Table 2.1: Quality of river waters from 1987-2002  
(Source: Department of Environment Malaysia, 2012)

Year	Clean	Slightly polluted	Very polluted
2005	338	166	90
2006	335	180	58
2007	368	164	48
2008	334	197	48
2009	306	217	54
2010	293	203	74
2011	275	150	39
2012	278	161	34

### 2.2.2 Global water shortage

Presently, potable water scarcity is affecting most of the countries worldwide such as Asia and Sub-Saharan Africa regions that have the most water-stressed countries as shown in **Figure 2.3** and **2.4**. Water scarcity is defined as the point at which the aggregate impact of all users impinges on the supply or quality of water under



prevailing institutional arrangements to the extent that the demand by all sectors cannot be satisfied fully. (United Nations (UN), 2005). The indications of water scarcity are the decline in groundwater table and river pollution. In addition, by 2025 an estimated 1.8 billion people will live in areas plague by water scarcity and another two-thirds will live in water stressed regions.

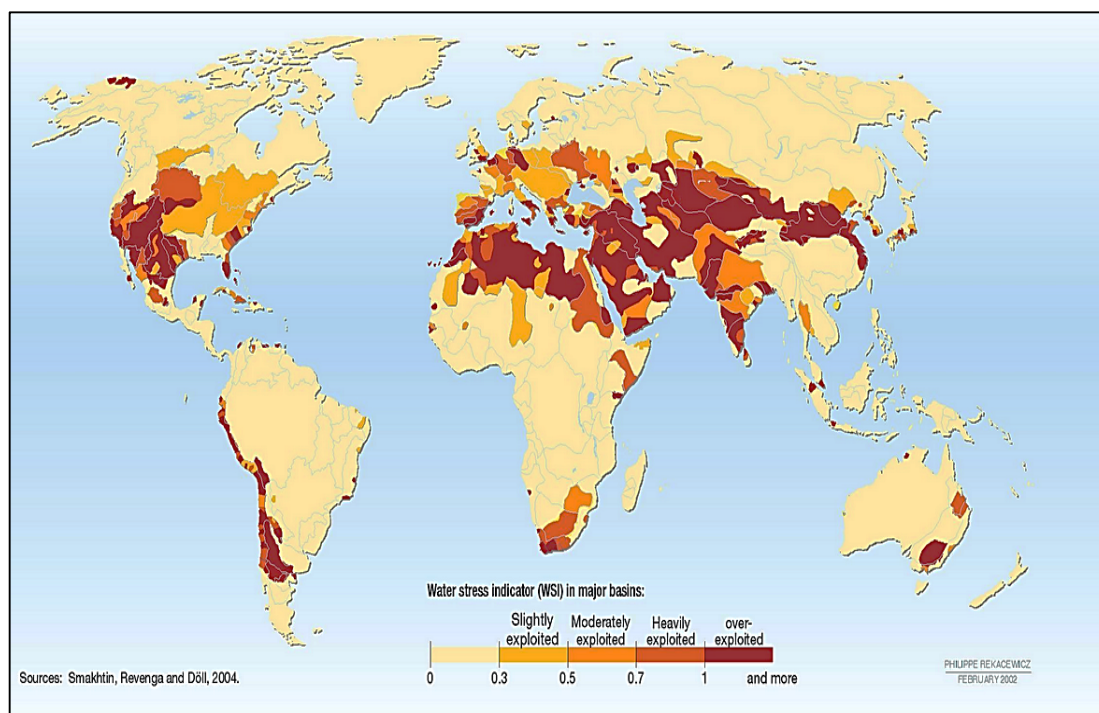


Figure 2.3: Water stress indicators in major river basins  
(Source: [www.unep.org](http://www.unep.org))



Figure 2.4: Dried up well in Guizhou Province.  
(Source: [www.waterpolitics.com](http://www.waterpolitics.com))

### 2.2.3 Water shortage in Malaysia

At present, Malaysia receives 3000 mm of rainfall every year which give about 990 billion m<sup>3</sup> of water (see **Figure 2.5**). It is estimated that the annual surface runoff is 566 billion m<sup>3</sup> - 147 billion m<sup>3</sup> is in Peninsula Malaysia, 113 billion m<sup>3</sup> in Sabah and 306 billion m<sup>3</sup> in Sarawak. The remaining 360 billion m<sup>3</sup> are then lost through the evaporation process and 64 billion m<sup>3</sup> towards groundwater recharge (Malaysia, 2000). Although Malaysia is gifted with abundant water resources, it is one of the many countries that are entering the era of severe water shortage due to factors such as inexorable growth in population and development. Thus, causing excessive pressure on the environment and water resources in the country as the water continues to be degraded. Poor water quality that was resulted from this situation can be associated with the economic aspects; increased in water treatment cost, effects on the economic activities and the increase in health-related costs.

The primary cause for the decline is because of overuse and misuse of land and water resources in river basins in both industrialized and developing countries. Thus, it contributes to the shortage of water in most parts of the country. This problem has affected the country particularly the Klang Valley. If this problem is not resolved, the Selangor state may experience regression in development as it will impede the economic growth as many factories postponed their operations due to water deficiency. Currently, the water level at Sungai Selangor dam which supplies water to 1.9 million users or 62 per cent of users especially in Kuala Lumpur, Gombak, Petaling Jaya, Shah Alam and Klang is at critical level (see **Figures 2.6 and 2.7**). Following the checks by the officials at Selangor Water Management Authority (LUAS), as of 1 August 2014 the recorded water level at the dam stood at 33.46% below the minimum requirement of 55%. (The Malay Mail Online, 2014).

Furthermore, one of the reasons for water shortage in Malaysia is because the price of water is cheaper compared to other utilities such as electricity. In average, the cost of water bill for most Malaysians only amounts to 10% of the electricity bill. Thus, most consumers do not practice sustainable water consumption. According to Datuk Seri Peter Chin Fah Kui the Minister of Energy, Green Technology and Water, 70% of Malaysians overuse their water consumption and do not intend to change their lifestyle. At present, the consumption of water in Malaysia is the highest compare to

other neighbouring countries in South East Asia region. In average, Malaysia used about 226 litres of water per person daily which is above the daily recommended limit of 165 litres per day, while Singapore used 154 litres of water and Thailand used only 90 litres of water. Currently, Singapore is taking an initiative in lowering their water consumption and aims to lower it to 147 litres by 2020 (The Star, 2013).

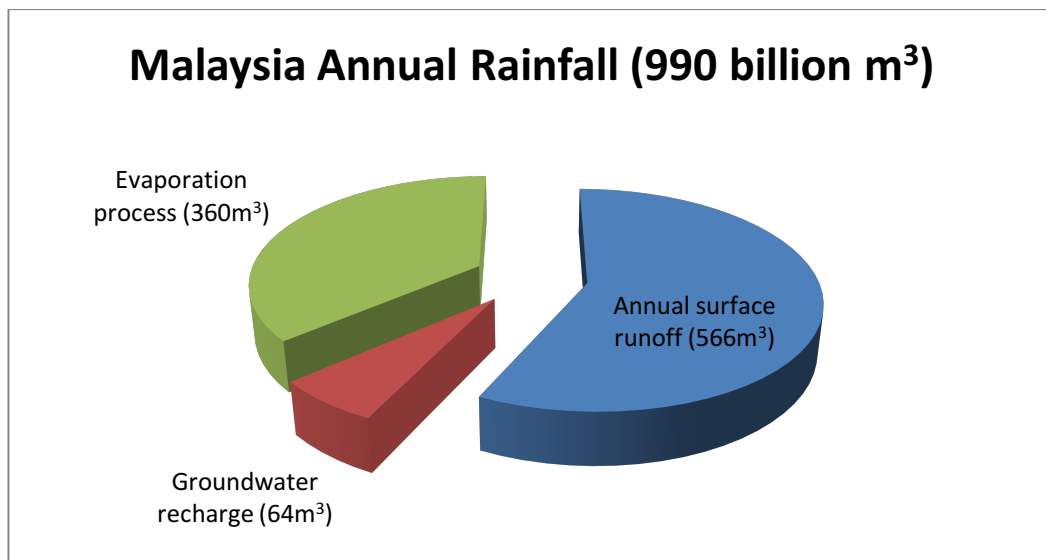


Figure 2.5: Malaysia annual water balance.

(Source: Malaysia Department of Drainage and Irrigation)



Figure 2.6: The depleting level of water at Sungai Selangor dam.





Figure 2.7: Residents stocking up water from Syarikat Bekalan Air Selangor (SYABAS) truck.

(Source: The Star, 2013)

**Table 2.2** below shows the increase in demand of water for domestic and industrial purposes and these figures continue to escalate from year 1980 to 2000. Since many development activities were done during the 1990's till 2000; there is a large increase in the total water demand during that 10-year period. While, **Figure 2.8** shows the percentage of water consumption for domestic and non-domestic for the year 2010 and 2011. There percentage of domestic usage was 0.3% lowered for year 2011 in contrast to 2010 while there was an increased in non-domestic usage.

Table 2.2: Domestic and Industrial Water Demand (million m<sup>3</sup>)

(Source: Department of Irrigation and Drainage (DID))

STATE	1980	1985	1990	2000
Perlis	9	9	16	37
Kedah	49	82	113	266
Penang	124	169	236	343
Perak	145	216	327	596
Selangor	470	658	787	1201
Negeri Sembilan	62	102	131	197
Malacca	30	43	61	112

Johor	159	258	338	578
<b>Total</b>	1046	1537	2009	3324

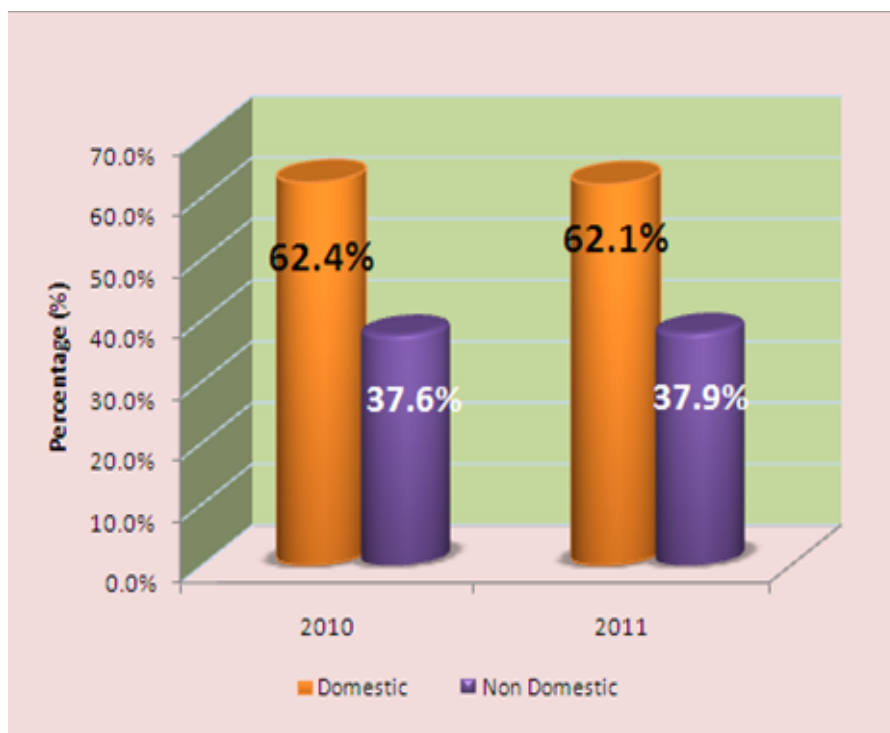


Figure 2.8: The total consumption of water for domestic and non-domestic uses in Malaysia in 2010 and 2011.

(Source: National Water Services Commissions).

#### 2.2.4 Water pollution

Water pollution is any change in physical, chemical and biological properties of water that has harmful effect on living things. Furthermore, it affects all major water bodies in the world such as lake, river and groundwater. Polluted water may cause harmful waterborne diseases such as diarrhoea and typhoid as it carries viruses and bacteria. In most cases, children are often affected by inadequate water supply as diseases are easily spread through water. It is estimated that for every 20 seconds a children die due to waterborne diseases (UNCF & WHO, 2009). Moreover, death by diarrhoea attributed to poor water supply, sanitation and hygiene are 3.4 million each year and 99% occur in developing world (WHO, 2008).

Sources of water pollution in Malaysia are heavy metals and ammonia, from sediments run-off and domestic wastes (see **Figure 2.9**). However, the major contributor to water pollution in Malaysia is from factories and agricultural wastes. Industrial production predominantly relies on water as it encompasses in many of its processes for example cleaning, heating and cooling. Rivers that are used as dumping outlet will affect not only the people and natural environment but the economy as well. Additionally, water pollution decreases the total water availability as the cost of treating polluted water is very high. In some instances, polluted water is not treatable for consumption. Urbanization especially within the catchment area changed the quality of runoff which then affects the water quality. Harmful contaminant from land surfaces that has been washed away by rain into the storm water also contributes to water pollution in rivers.



Figure 2.9: Polluted river in Sungai Tebrau, Johor  
(Source: [www.nst.com.my](http://www.nst.com.my))

## **2.3 Water quality and control**

Water quality is measured to ensure the health of river and its ecosystem. Good water quality for rivers is needed for the thriving of aquatic life. When the water quality conditions are not met, it will have detrimental effects on the organisms. To measure the water quality index in rivers, several parameters needed to be considered and it can be divided into several groups such as physical, chemical, radioactive and biological.

### **2.3.1 Water quality parameters**

#### **2.3.1.1 Temperature**

Water temperature is a measurement of the heat content of the water mass and the influences for the growth rate and survivability of aquatic life. Temperature affects the physical, biological and chemical characteristics of a river. The changes in temperature for each river varies depending on the interaction between the surface water and groundwater inflows. Moreover, wastes discharge can also affect the temperature as the effluents temperature is normally warmer than water.

#### **2.3.1.2 Turbidity**

Turbidity is the amount of fine particles or suspended sediments in water. The particles present in water may be organic such as algae or inorganic (e.g. sand, fine silts or clays). Moreover, the fine inorganic particles quantify the degree of light travelling through water is scattered. High turbidity caused by suspended sediment affects the penetration of light thus resulting in reduction of plant growth in the river and damaging the ecosystem (Said et al., 2004).

#### **2.3.1.3 Suspended sediments**

Sediments consist of particles with different sizes such as silt, sands and clays. The adverse effects of sediments are reduction in water quality, damage the fish gills, disturb the ecosystem by fill in the spaces between gravel where fish lay eggs, smoothen the gravel beds and it may also cause water pollution as it may carry

pollutants into the water system. Human activities such as logging and earthworks have increases the total sediments load in the river system through the erosion process.

#### **2.3.1.4 pH**

pH is the standard measurement of acidity and alkalinity. Low pH value indicates it is acidic while high pH indicates alkaline conditions. Moreover, pH value of 7 is defined as neutral condition and most water in Malaysia is in this zone. The pH range for groundwater that is used for drinking purposes is 6.5-8.5 and it may also be 6.0 especially in shallow unconfined groundwater (from wells less than 30m deep).

#### **2.3.1.5 Dissolved oxygen**

Dissolved oxygen is a measurement of the amount of oxygen that is freely available in water and directly dependent on temperature. Moreover, the colder the temperature of water, the more oxygen it can hold on (Said et al. 2004) and prolong hot temperature may reduce the oxygen concentrations as it promotes bacterial activity.

#### **2.3.1.6 Biochemical Oxygen Demand**

Biochemical Oxygen Demand (BOD) is the amount of dissolved oxygen needed by aerobic biological organisms in a body of water to break down organic material existing in a given water sample at certain temperature over a particular time period. BOD also determined the oxygen required by pollutants to stabilize domestic and industrial wastes. Moreover, BOD is used as an indication for organic water quality. Additionally, BOD test is used to measure the amount of biodegradable wastes that are present in water (WSDE, 2002) and the amount of food for bacteria. It is estimated that the amount of BOD loading being discharged in Malaysia is 883,391.08 kg/day.

### **2.4 Water Quality Index**

Water quality index (WQI) is a method that assesses the quality of water by combining the measurement of selected physical, biological, chemical and radioactive parameters (Cude et.al, 2001). WQI is a unitless number that varies from 1 to 100 and higher value

represents better water quality. Moreover, WQI is important in estimating the water quality from different sources and observing the changes that occurs in the water as a function of time and other factors (Abassi, 2002).

WQI is a mathematical tool to convert bulk water quality data into a single digit. Parameters such as BOD, dissolved oxygen and pH are measured and compared using the classification tables. These parameters then help in classifying the water into excellent, good, fair, poor and very poor. WQI that has been used by Malaysia Department of Environment is based on opinion-poll and is measure using six parameters such as dissolved oxygen, biological oxygen demand, pH value, suspended solids, chemical oxygen demand and ammonical nitrogen (Khuan et.al, 2002). The formulas used to calculate WQI is:

$$WQI = 0.22 SI_{DO} + 0.19 SI_{BOD} + 0.16 SI_{COD} + 0.16 SI_{SS} + 0.15 SI_{AN} + 0.12 SI_{pH} \quad (2.1)$$

Where,

WQI = Water quality index

$SI_{DO}$  = Sub-index of dissolved oxygen

$SI_{BOD}$  = Sub-index of biological oxygen demand

$SI_{COD}$  = Sub index of chemical oxygen demand

$SI_{AN}$  = Sub-index of ammonical nitrogen

$SI_{SS}$  = Sub-index of suspended solid

$SI_{pH}$  = Sub-index of pH.

Sub-index for dissolved oxygen (DO) (in % saturation):

$$SIDO = 0 \quad \text{for } DO < 8 \quad (2.2)$$

$$= 100 \quad \text{for } DO > 92 \quad (2.3)$$

$$= -0.395 + 0.030DO^2 - 0.00020DO^3 \quad \text{for } 8 < DO < 92 \quad (2.4)$$

Sub-index for BOD:

$$SI_{BOD} = 100.4 - 4.23BOD \quad \text{for } BOD < 5 \quad (2.5)$$

$$= 108e^{-0.055BOD} - 0.1BOD \quad \text{for } BOD > 5 \quad (2.6)$$

Sub-index for COD:

$$SI_{COD} = -1.33COD + 99.1 \quad \text{for } COD < 20 \quad (2.7)$$

$$= 103e^{-0.0157COD} - 0.04COD \quad \text{for } COD > 20 \quad (2.8)$$

Sub-index for AN:

$$SI_{AN} = 100.5 - 105AN \quad \text{for } AN < 0.3 \quad (2.9)$$

$$= 94e^{-0.573AN} - 5 \frac{1}{2} AN - 2 \frac{1}{2} \quad \text{for } 0.3 < AN < 4 \quad (2.10)$$

$$= 0 \quad \text{for } AN > 4 \quad (2.11)$$

Sub-index for SS:

$$SI_{SS} = 97.5e^{-0.00676SS} + 0.05SS \quad \text{for } SS < 100 \quad (2.12)$$

$$= 71e^{-0.0016SS} - 0.015SS \quad \text{for } 100 < SS < 1000 \quad (2.13)$$

$$= 0 \quad \text{for } SS > 1000 \quad (2.14)$$

Sub-index for pH:

$$SI_{pH} = 17.2 - 17.2pH + 5.02pH^2 \quad \text{for } pH < 5.5 \quad (2.15)$$

$$= -242 + 95.5pH - 6.67pH^2 \quad \text{for } 5.5 < pH < 7 \quad (2.16)$$

$$= -181 + 82.4pH - 6.05pH^2 \quad \text{for } 7 < pH < 8.75 \quad (2.17)$$

$$= 536 - 77.0pH + 2.76pH^2 \quad \text{for } pH > 8.75 \quad (2.18)$$

The water quality is then classified according to the Malaysia Water Quality Index as shown below:

Table 2.3: Malaysia water quality index class  
(Source: Department of Environment Malaysia, 2006)

Parameters	Class				
	I	II	III	IV	V
AN	< 0.1	0.1-0.3	0.3 – 0.9	0.9 – 2.7	> 2.7
BOD	< 1	1 – 3	3 – 6	6 – 12	> 12
COD	< 10	10 – 25	25 – 50	50 – 100	> 100
DO	> 7	5 – 7	3 – 5	1 - 3	< 1
pH	> 7	6 – 7	5 – 6	< 5	< 5
TSS	< 2.5	25 – 50	50 - 150	150 - 300	> 300
WQI	> 92.7	76.5 – 92.7	51.9 – 76.5	31.0 – 51.9	< 31.0

Moreover, the classification of Malaysia water quality can be refer to another standard which is the Interim National Water Quality Standard (INWQS) as some of the parameters are not presence in the Department of Environment water quality standard such as the turbidity level and the Total Dissolved Solid. **Table 2.4** below shows the excerpt of INWQS standard and its water quality classes may differ in value in comparison to the DOE water quality standard.

Table 2.4: Excerpt of International Water Quality Standard

Parameters	Units	Class I	Class IIA	Class IIB	Class III	Class IV	Class V
BOD	mg/l	1	3	3	6	12	>12
COD	mg/l	10	25	25	50	100	>100
DO	mg/l	7	5-7	5-7	3-5	<3	<1
TDS	mg/l	500	1000	-	-	4000	-
Turbidity	NTU	5	50	50	-	-	-

Table 2.5: INWQS class definition

Class	Classifications
I	No treatment required
IIA IIB	Conventional treatment required Recreational use body contact
III	Extensive treatment required
IV	Irrigation
V	None of the above

## 2.5 Water filtration processes and technology

Many regions around the world are currently suffering from water scarcity, water pollution and deterioration in water quality. At present, these are the main problems associated to the current and future water resources. Due to demand, polluted surface water and wastewater are being treated to higher quality standard fit for human consumption and other purposes. Water purification is the process of removing undesirable chemicals, materials and biological contaminants from contaminated



water (Ab. Aziz, 2011). Water treatments such as flocculation, sedimentation, and filtration are methods being incorporated to remove suspended particles, dissolve organic matters and viruses. However, membrane filtration is currently gaining popularity in water treatment as this process have high efficiency and less operating cost in contrast to conventional methods that have been mentioned before. This section will present the methods of filtration that are currently available in the market.

### 2.5.1 Water treatment plant and process

Water sources from surface water and reservoirs will be treated in the water treatment plant first before being distributed to users (see **Figure 2.10**). This is to ensure that the water is clean from contaminants, sediments and harmful chemicals. The treatments involved may be physical process (settling and filtration), biological process (slow sand filters) and chemical process (coagulation). The treatments that the water will undergo are as follow:

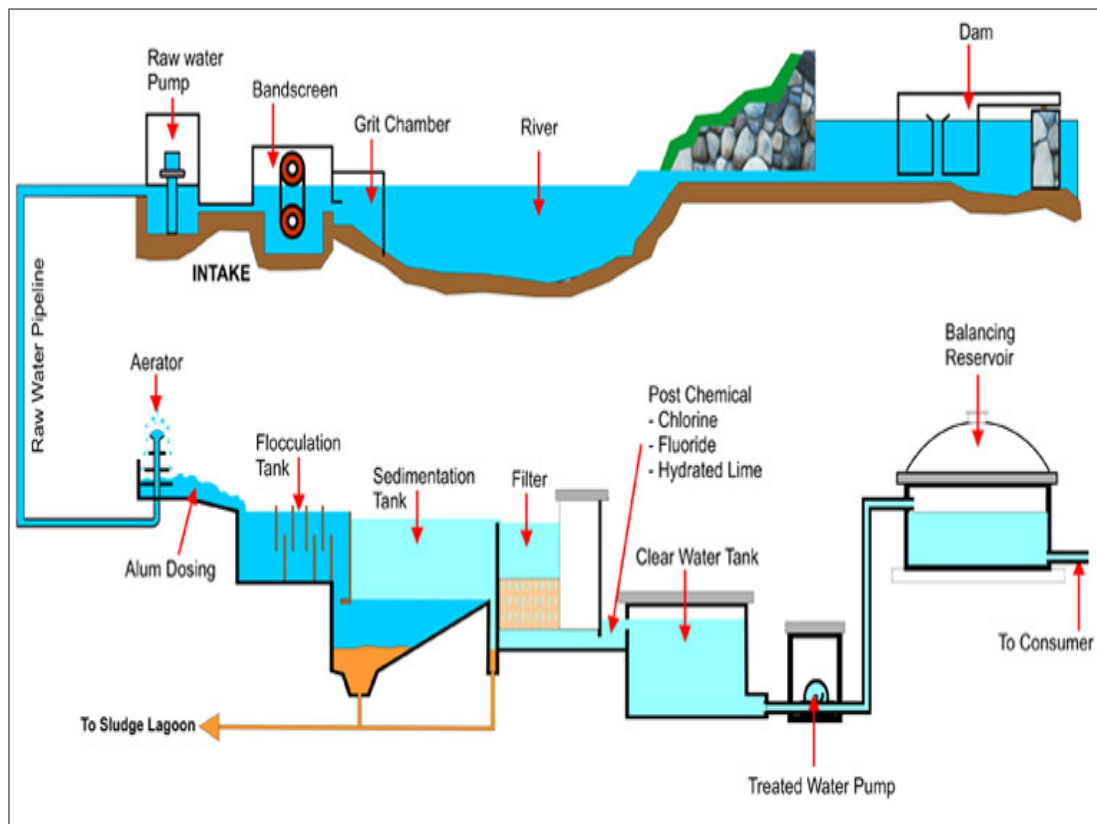


Figure 2.10: The typical water treatment process.

(Source: Puncak Niaga Holdings Berhad)

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